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Digging Out the Root Cause: Nunn-McCurdy Breaches in Major Defense Acquisition Programs

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Panel 8. Causal Factors for Cost Breaches in DoD Acquisition

Wednesday, May 14, 2014	
3:30 p.m. – 5:00 p.m.	<p>Chair: Gary R. Bliss, Director, Performance Assessments and Root Cause Analyses (PARCA), Office of the Assistant Secretary of Defense (Acquisition)</p> <p>Regulatory Burden and Poor Defense Acquisition Program Outcomes R. Bruce Williamson, Institute for Nuclear Security Justin Roush, University of Tennessee</p> <p>A Model for Understanding the Relationship Between Transaction Costs and Acquisition Cost Breaches Diana Angelis, Naval Postgraduate School Laura Armey, Naval Postgraduate School Carl Biggs, U.S. Navy</p> <p>Digging Out the Root Cause: Nunn-McCurdy Breaches in Major Defense Acquisition Programs Bill Shelton, RAND Corporation Irv Blickstein, RAND Corporation Jerry Sollinger, RAND Corporation Charles Nemfakos, RAND Corporation</p>



Digging Out the Root Cause: Nunn-McCurdy Breaches in Major Defense Acquisition Programs

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Abstract

Continuing concern over defense acquisition has led Congress to direct the establishment of an office in the Department of Defense to oversee the conduct of root cause analyses on programs that have incurred Nunn-McCurdy breaches. This paper focuses on one such program. RAND analysis of several programs with Nunn-McCurdy breaches reveals they share several common causes. However, each program is different, and those differences suggest that policymakers should be wary of applying policies that assume all program cost increases stem from common causes.

Introduction

Congress has long been concerned about cost overruns in major defense acquisition programs. Beginning in the 1970s when it expropriated the Selected Acquisition Reports (SARs) as a gauge of program performance, Congress has continued to create mechanisms to gain insights into program execution. However, SARs did not become a legal reporting requirement until 1975, with Public Law 94-105. (Leach, 2002). In 1981, Senator Samuel Nunn and Congressman David McCurdy introduced the Nunn-McCurdy Amendment to the Department of Defense Authorization Act of 1982. (Public Law 97-86, 1981) The purpose of the amendment was to establish congressional oversight of defense weapon system acquisition programs whose costs rise above certain limits. The Nunn-McCurdy Amendment defined two types of unit cost: total program acquisition unit cost (PAUC), which is the sum of development funding and procurement funding divided by units procured and average procurement unit cost (APUC), which is the procurement funding divided by the number of units procured. Cost growth of a weapon system was measured by how much the unit costs in 1982 exceeded the same respective unit costs in the weapon system's SAR dated March 31, 1981. Hence, the amendment applied only to those major weapon systems with March 31, 1981 SARs. The original amendment required the Secretary of Defense to notify Congress when a major weapon system unit cost growth exceeded 15%. If unit cost growth exceeded 25%, the program was assumed terminated unless the Secretary of Defense submitted written certifications to Congress within 60 days of determining that a breach had



occurred. The provisions were made permanent in the 1983 Authorization Act, and these breaches are commonly referred to as Nunn-McCurdy breaches.

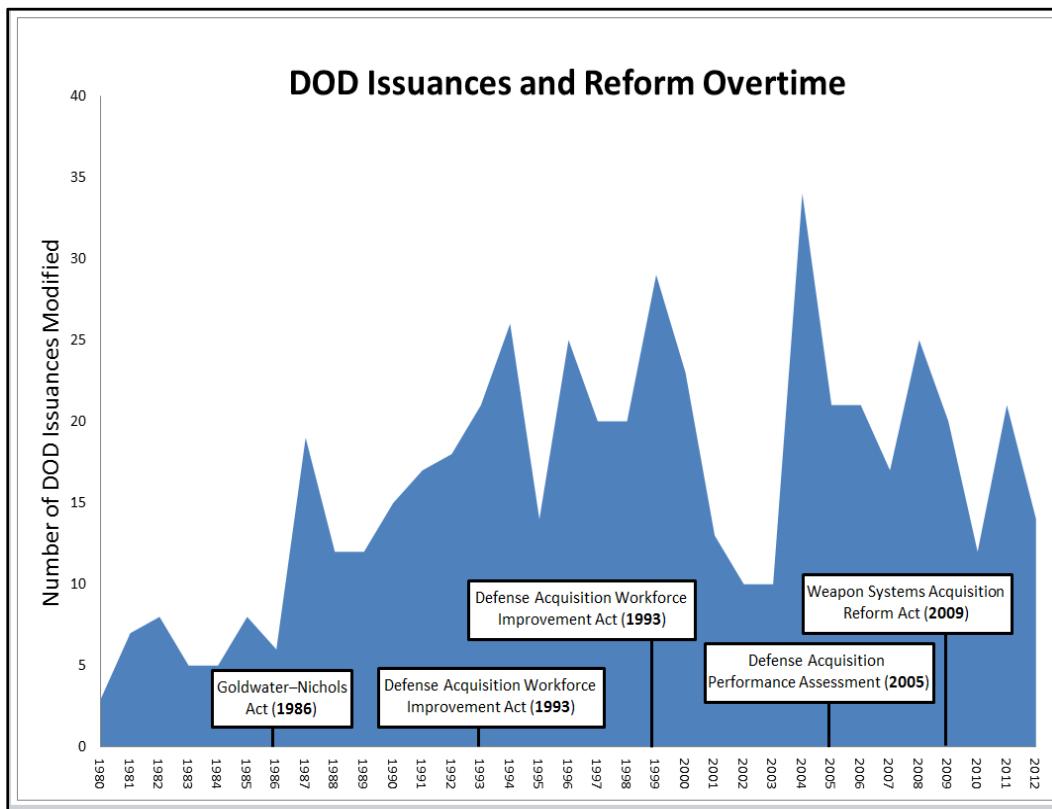


Figure 1. DoD Issuances and Reform Over Time

Every two years since 1990, Congress has tasked the Government Accountability Office (GAO) to create a list of issues that are considered to represent high risk. The issues on the high-risk list are those that require attention either because they are particularly vulnerable to mismanagement, waste, fraud, or abuse or need modification to address major economy, efficiency, or effectiveness challenges. The last high-risk list came out in January 2011, and Department of Defense weapon systems acquisition is on that list (GAO, 2011). Overtime there have been many external as well as internal initiatives to reform the acquisition system. Figure 1 captures the Department of Defense Issuances as well as a few of the major initiatives pushed by Congress and by the DoD's leadership where the acquisition system has been the prime focus. It is clear that over time these efforts for reform have increased.

The Weapon Systems Acquisition Reform Act of 2009 is the latest effort and it incorporates definitions for two categories of weapon system breaches: significant and critical (PL 111-23, 2009). A breach is determined by comparing original and current PAUC and APUCs, and a breach can occur if the unit costs exceed either the current or the original baseline by specific percentage. Thresholds appear in Table 1.



Table 1. Breach Thresholds

Level	Unit Cost	Baseline	Threshold
Significant	PAUC	Current	>=15%
	APUC	Current	>=15%
	PAUC	Original	>=30%
	APUC	Original	>=30%
Critical	PAUC	Current	>=25%
	APUC	Current	>=25%
	PAUC	Original	>=50%
	APUC	Original	>=50%

Congressional interest in and efforts to contain spending on defense acquisition has continued. The Weapon Systems Acquisition Reform Act (WSARA) of 2009 established a number of requirements that affected the operation of the Defense Acquisition System and the duties of the key officials who support it, including the requirement to establish a new organization in the Office of the Secretary of Defense (OSD) with the mandate to conduct and oversee performance assessments and root cause analyses (PARCA) for major defense acquisition programs (MDAPs; PL 111-23, 2009).

The act assigned the resulting PARCA organization five primary responsibilities:

1. Carrying out performance assessments of MDAPs;
2. Performing root cause analysis (RCA) of MDAPs whose cost growth exceed the threshold as detailed in the Nunn-McCurdy provision;
3. Issuing policies, procedures and guidance governing the conduct of performance assessments and root cause analyses;
4. Evaluating the utility of performance metrics used to measure the cost, schedule, and performance of MDAPs; and
5. Advising acquisition officials on performance issues that may arise regarding an MDAP.

The PARCA office has a relatively limited staff, and reporting deadlines for breaches are short, less than two months. Therefore, the director has asked outside organizations, primarily federally funded research and development centers, to assist in conducting the root cause analyses directed by the law. RAND has supported the PARCA office by analyzing nine programs: the Zumwalt-Class Destroyer (DDG-1000), the Joint Strike Fighter F-35, Longbow Apache Helicopter, Wideband Global Satellite, Excalibur artillery round, the Navy Enterprise Resource Program.¹

¹ RAND is in the process of completing analysis of the Joint Tactical Radio System Ground Mounted radio, the P-8A Poseidon aircraft, and modifications to the Global Hawk Unmanned Aerial Vehicle.



Purpose

This article has four purposes. First, it briefly describes the methodology RAND developed to carry out root cause analyses. The approach to root cause analyses has matured over time, and it might prove useful to other organizations that either must do a root cause analysis or wish to understand what the process involves. Second, it presents an example of such analyses, the Wideband Global Satellite, a program with both significant and critical breaches. Third, the article provides insight into the causes of breaches across several programs. Fourth, it offers some lessons learned about breaches and how to avoid them.

Methodology for Root Cause Analyses (RCA)

Congressional deadlines for RCA are tough to meet for two reasons. First, time available to do them is short. Depending on the circumstances, the RCA must be done in either 45 or 60 days.² Second, each RCA is unique because each program is unique. Thus, no “cookbook” spells out all the components and identifies key documents and their locations. RAND’s experience has enabled it to develop a generic methodology, depicted in Figure 2.

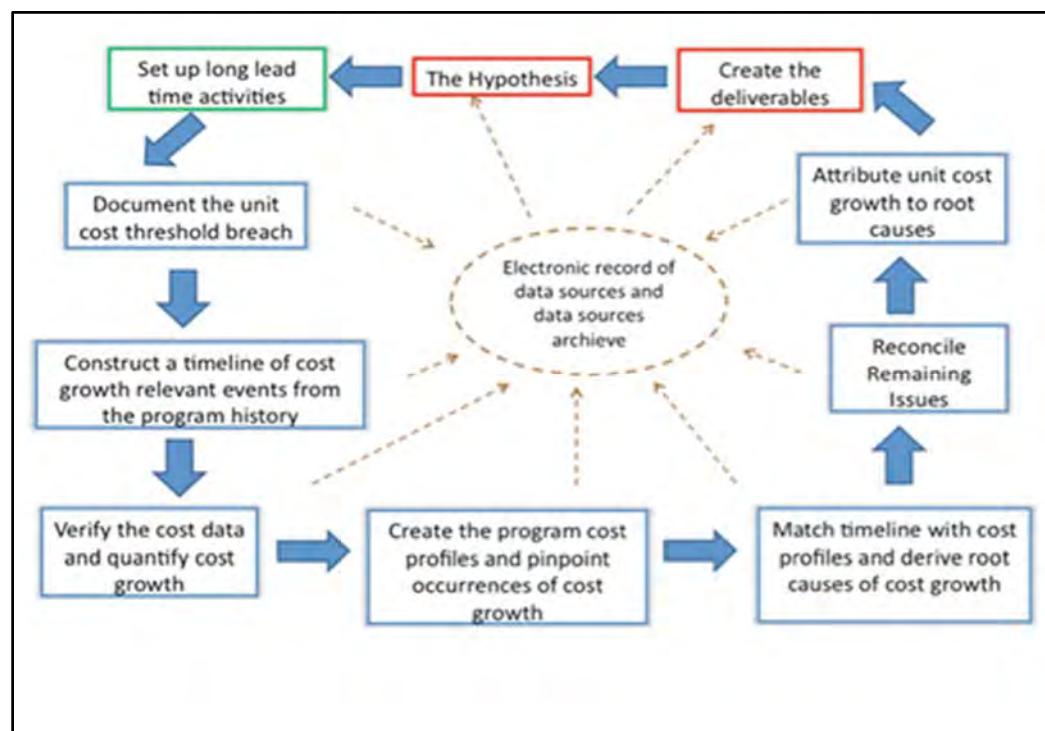


Figure 2. Generic RCA Methodology

² The 45-day period between program manager report of a breach and military department secretary notification of a critical unit cost breach to Congress starts the day after the initial report of the breach to the Service Acquisition Executive. The 60-day period within which the Secretary of Defense must submit his program recertification decision to Congress starts on the day after the due date of the first SAR that reports the breach.

The process is designed to use the short time available as efficiently as possible. It begins with a hypothesis about what caused the program to breach the threshold. That hypothesis guides many of the subsequent activities, including setting up interviews with key players both in industry and government, which can take some time to arrange. Work has to proceed in parallel so that the required products can be delivered to the PARCA office in a timely way. In the RCAs performed to date, the PARCA office has requested the deliverables listed below:

- a completed root cause matrix in the format supplied by the PARCA office,
- a summary narrative,
- a set of briefing charts based on the narrative, and
- a full RCA report

All deliverables except the full RCA report should be supplied by PARCA office deadlines to ensure that these materials can be used to support the recertification decision.

Root Cause Analysis of Programs

Wideband Global Satellite³

The WGS program was funded in 2001 to acquire an unprotected wideband SATCOM capability by using a commercial off-the-shelf satellite bus and Ka-band technology and thereby meet the DoD's insatiable demand for military satellite communications (SATCOM). WGS provides both X-band communications compatible with the older Defense Satellite Communication System (DSCS) platforms and Ka-band broadcast capability like the Global Broadcast System (GBS). Throughput for each satellite is estimated at over two gigabits per second (Air Force Handbook, 2007).

The program consists of two phases or "blocks." Block I of WGS comprises three satellites, the last of which went in orbit in December 2009. WGS Block II consists of three additional satellites, two contracted for the United States to replace aging DSCS and GBS satellites and a third wholly purchased by Australia in exchange for a percentage of global WGS bandwidth. Block II satellites are essentially the same as Block I with a high-bandwidth bypass feature for aerial intelligence, surveillance, and reconnaissance platforms (*Aviation Week & Space Technology*, March 8, 2010, p. 16.). With the delays and eventual cancellation of the Transformational Satellite Communications System, the DoD decided to procure the seventh and eighth WGS satellites, Block II Follow-on (IIf), with a planned total buy of 12 WGS satellites to meet future broadband communication requirements.

The Nunn-McCurdy Breach

The unit cost to the government of WGS Block II was roughly 50% more expensive than Block I (\$377 million compared with \$239 million), and Block IIf is again roughly 50% more expensive than Block II (\$574 million compared with \$377 million).

Table 2 illustrates the breach. The 27% increase between the current estimate and the current acquisition program baseline (APB) [third column] exceeds the 25% threshold for

³ We are indebted to our RAND colleague, Martin Libicki, for his analysis and description of the root causes of the Nunn-McCurdy breach on the Wideband Global Satellite.



a “critical” breach (the 40% increase [fourth column] between the current estimate and the original APB represents a “significant” but not “critical” Nunn-McCurdy breach).

Table 2. WGS APUC (Exclusive of Launch Costs)

	Original APB	Current APB/ Original APB	Estimate/ Current APB	Estimate/ Original APB
Block	I	I & II	I, II, IIIf	I, II, IIIf
Satellites	1-3	1-5	1-8*	1-8*
Contract type	FFP ⁴	FPIF	FPIF	FPIF
APUC	\$268m	\$294m	\$374m	\$374m
Unit Cost**	\$239m	\$377m ⁵	\$574m	\$574m
% Δ APUC	-	110%	127%	140%
% Δ Unit Cost	-	158%	152%	240%

* WGS 6 was purchased for Australia and does not show up in U.S budget accounts.

** That is, cost to the Government.

The averages, in turn, permit calculation of a unit cost for Blocks I, II, and Block II follow-on but not in a straightforward manner.⁶ In real (Base Year [BY] 2001 \$) terms, the PAUC of the WGS satellite rose 58% between Block I and II (from \$239 million to \$377 million). Unit costs between Block II and Block II follow-on (IIIf) are projected to rise 52% (from \$377 million to \$574 million). Table 3 indicates when each WGS satellite was ordered, when delivered, and the difference in years; Figure 3 indicates the interval during which the USAF-purchased WGS satellites were built and launched. The table indicates a large gap between WGS Block I and WGS Block II and a smaller gap between WGS Block II and WGS Block IIIf. However, the time between program approval and launch for WGS Block I was five to seven years, and the expected cycle-time for WGS Block II is shorter, four to five years. If current launch dates for Block IIIf prove accurate, then the gap between Block I and Block II will be somewhat smaller than the gap between Block II and Block IIIf.

Table 3. WGS Order and Launch Years

	Satellite	Budget Year	Launch Year	Difference in Years
Block I	1	2002	2007	5
	2	2002	2009	7
	3	2003	2009	6
Block II	4	2007	2011*	5*
	5	2008	2012*	4*
Block IIIf	6 (Aus.)	2009	2013	4*
	7	2011	2016	5
	8	2012	2017	5

*These are the launch dates taken from the President's 2012 budget

⁴ FFP = Firm Fixed Price; FPIF = Fixed Price Incentive Fee

⁵ Cost claims currently made by Boeing would suggest that the true cost of the first three satellites was roughly \$377 million.

⁶ Note that the original APB was \$268 million (fifth row) per satellite, but the unit cost is now estimated to be \$239 million (fourth row). The difference between the two is accounted for by the fact that other government costs ended up \$29 million per satellite lower than estimated.



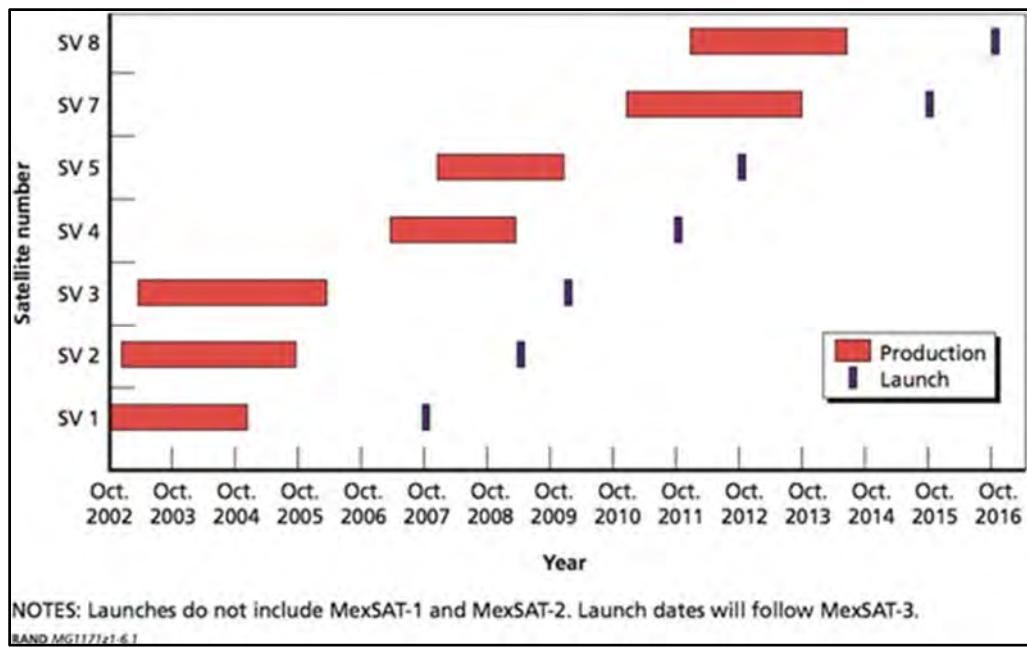


Figure 3. WGS Production/Launch Periods

Sources of the Nunn-McCurdy Breach

The WGS cost breach has two components: the increase in unit costs between Block I and Block II satellites and the increase in unit costs between Block II and Block IIIf satellites. The first difference was ascribed to “what proved to be an artificially low cost for the original three vehicles under a firm fixed-price contract” (SECAF letter, March 8, 2010). We focus on the latter cost increase, largely because it is the current one and thus far more relevant to decisions to be made on the WGS program.

Table 4, shows both blocks in terms of target and ceiling costs. The latter includes margin sufficient to account for the possibility of cost overruns on the FPIF work (combining advanced procurement, base procurement, and launch support costs).

How do \$555 million and \$410 million (in current dollars) compare with the aforementioned \$574 million and \$377 million (in BY2001 dollars)? Table 5 illustrates the difference.



Table 4. Program Office Unit Cost Breakdown (Current Dollars)

	BY	Target	Ceiling
Block II	2007	\$355m	\$410m
Block II follow-on	2011	X	\$555m

Table 5. Relating Base Year and Current Year Costs (\$ in Millions)

	Block II	Block IIIf
Unit Cost (BY 01\$)	377	574
Inflation factor to current costs	1.14	1.207
(BY07)	(BY11)	
Unit Cost current year dollars	430	693
Less Storage and Factory Restart	4	73
Subtotal	426	620
Less Other Gov't Costs	71	65
Subtotal (from Table 4)	355	555

Several features merit note. First storage and factory restart costs were very small in going from Block I to Block II but substantial in going from Block II to Block IIIf even though the gap before restarting production was four years for Block II, and only two-and-a-half years for Block IIIf. We could not explain this difference. Second, in both cases, Other Government Costs (estimated based on data from the program office and SAF) are fairly large but roughly the same in both cases. These costs include contracting office and engineering costs; it was *estimated* by subtracting known cost components from total cost components and checked for overall reasonableness and consistency.

Third, and most important, the bottom line unit price figure for the Block II satellite is \$355 million rather than the \$410 million ceiling price. Why? The \$355 million represented the contracted, hence targeted, price of the satellites; if Boeing costs were higher than \$355 million, then, under the terms of the contract, the federal government would reimburse Boeing only for 80% of those additional costs. The \$410 million was the ceiling price; Boeing would have to absorb all costs in excess of that amount. Building the Current APB APUC (for Blocks I and II) out of the contract price but building the Expected APB APUC (for Blocks I, II, and IIIf) out of the ceiling price essentially compares apples and oranges. In effect, the WGS Program Office built a 15% hedge factor into the price. We cannot explain the programmers' motivation for doing so particularly because it led to a critical Nunn-McCurdy breach that otherwise could have been avoided. Whether this difference represents their lack of confidence in the estimate can only be a matter of speculation. Were this 15% removed, then the unit cost of Block IIIf would have been \$516 million (in current dollars) rather than \$574 million yielding an APUC of \$357 million, or an increase of 22 rather than 27% (that is, a "significant" rather than "critical" breach).

Nevertheless, \$555 million is still a substantial increase over \$355 million—and needs to be explained. Table 6 lists the various factors.



Table 6. Cost Increase Between Block II and IIf (Current Year Dollars)

Increase Component	Block II
1. Boeing Price (BY 2007\$)	\$355m
2. 3% Cost overrun	\$11m
3. Actual unit costs (BY 2007\$)	\$366
4. <i>Four years inflation at 3.5% per year</i>	1.147 ^a
5. Expected unit cost circa 2011	\$420m
6. Extra tests	\$2m
7. Higher component prices for 3 items	\$35m
8. Higher component prices overall	\$25m
9. Subtotal	\$482m
10. Risk premium of 15 percent	\$555m

Note. ^a(1.035x1.035x1.305x1.035 = 1.147 x \$366m = \$420m)

We start with the unit price of \$355 million. Next we add the current cost overrun of 3% (\$11 million; although the final cost overrun may be higher or lower, we presume that cost overruns experienced to date establish a new baseline for what it really costs to build a WGS): hence \$366 million. The next adjustment, line 4, factors in four years' worth of inflation at 3.5% per year (as calculated by the program office based on historic experience in satellite component and manufacturing costs).⁷ Hence, the \$420 million in line 5. Next comes \$2 million for additional tests not required for Block II, \$35 million (as calculated by Boeing) to pay for three critical components that might otherwise go out of production,⁸ and \$25 million (also as calculated by Boeing) for cost increases in other components at risk in the supply chain. Hence, the subtotal of \$482 million in line 9. The last adjustment arises from the accounting artifact noted above—the difference between contract costs used to calculate Block II prices and the ceiling cost used to calculate Block IIf prices. This brings us to the \$555 million that the program office uses to calculate unit costs for Block IIf.

Explaining the Cost Differences

The \$60 million in component cost inflation (over and above the normal 3.5% a year) shown in rows 7 and 8 of Table 6 requires further explanation. Reflecting a general shift in market requirements, Boeing shifted its commercial satellite offerings from its HS702HP (high-power) bus to its HS702MP (medium-power) bus. This shift has left WGS supporting the production of parts that no longer have much commercial demand, thereby raising the cost of these components. That noted, Boeing also claims that the cost ratio between bus and payload is expected to remain constant and the cost ratio between component costs and Boeing's costs is also expected to remain constant. Both imply that its internal costs have also risen more or less proportionately with component costs. This may be reflected in the charges associated with the cold factory restart noted earlier. Figure 4 indicates a sharp decline in commercial satellite production at about the same time that WGS production started. In the eight years before 2008, Boeing launched 11 commercial satellites; from 2008 to 2016, it plans to launch six. Although the pace of satellite construction has

⁷ Note that this 3.5% exceeds the 1.8% used as an overall price deflator by OSD to convert constant into current dollars.

⁸ The xenon ion propulsion system [XIPS], certain transponders, and a crypto box



recovered, it has not returned to earlier levels that characterized the first few years of this century.

Component cost inflation also reflects a broader phenomenon, the growing divergence between WGS and its civilian counterpart. Commercial products change constantly; military products change infrequently (but in relatively large chunks) and, in the case of MILSPEC products, may not change at all precisely because product qualification is both tortuous and tortuous. In effect, the WGS, born as a modification to a commercial business line, has evolved to a program that is primarily military. As noted, the WGS satellite bus has diverged from its civilian counterpart. The payload of the WGS satellite consists of Ka-band transponders and X-band transponders and channelizers to switch between the two. X-band is primarily military to begin with. The commercial market had flirted with Ka-band 10 years ago, but the trend towards terrestrial (fiber optics and cell phones) rather than satellite-based communications has dampened industry's interest in exploring different spectra whose primary virtue is that it is largely unclaimed. Furthermore, the global business of U.S. satellite manufacturers has been hampered by increasingly stringent application of International Traffic in Arms Regulations (ITAR) rules starting 10 years ago. Components that once could be supported from both WGS and commercial sales increasingly rely on the WGS market, and suppliers must be paid a premium to remain in the market. Similarly, former WGS workers who could count on transferring their skills into very similar commercial work when gaps appear in WGS face a harder transition. As one observer notes,

In its 10-year history, the Boeing division's main platform, the 702, has commonly served big commercial requirements, such as the three current orders for DirecTV and two for Sky Terra. But the platform also has been used for many of the company's major government programs, most prominently the Wideband Global Satcom (WGS) network of six spacecraft that replaces the Defense Satellite Communications System. ... WGS and two other major government programs—the Global Positioning System IIF and GOES N-P series—have provided 90% of Boeing's recent work. To redress that imbalance, the company began looking for new commercial market entries four years ago and concluded it could take advantage of the 702's flight software, avionics and power management systems to develop a smaller bus. (Mecham, 2009)

The days when commercial sales could buoy the resources put into the WGS program between one buy and the next are gone. The economics of WGS increasingly depend on the pace and scheduling of WGS buys alone.



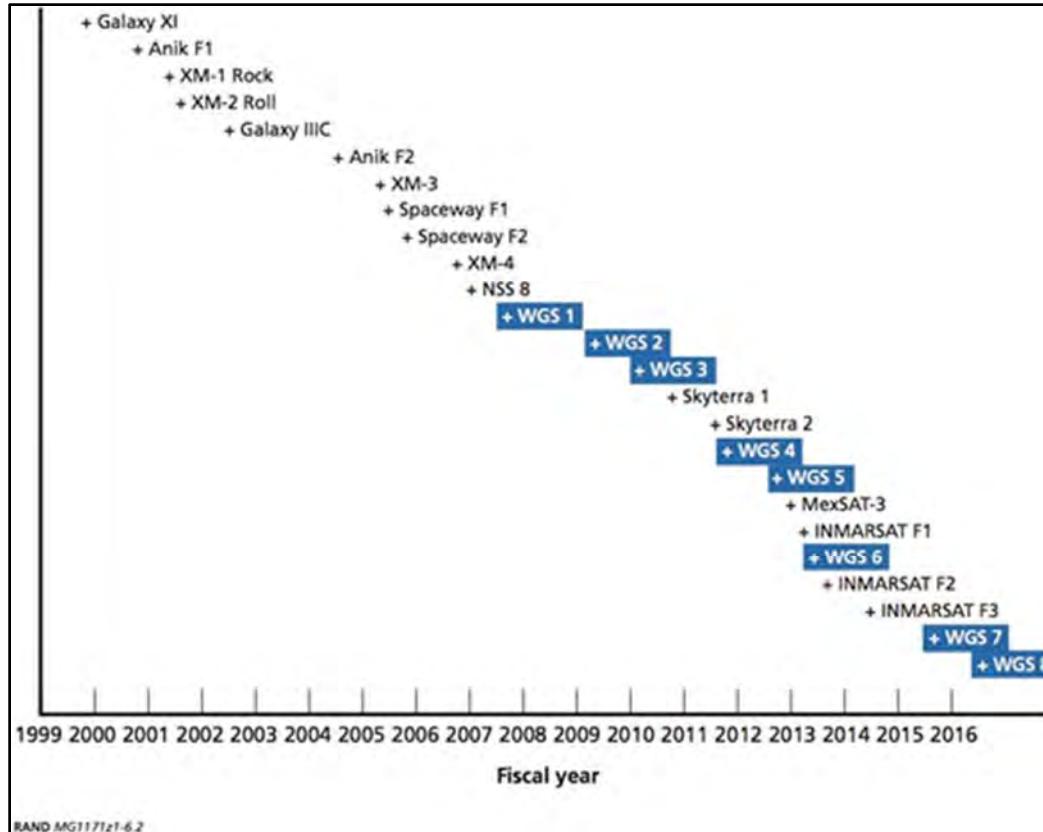


Figure 4. Launch Dates for Boeing-Produced Satellites

Root Cause Analysis

The 52% increase between Block II and Block IIIf unit pricing is primarily due to the first three factors listed in Table 7. Such results are necessarily limited by the 60-day window allowed for investigation under the Nunn-McCurdy legislation that curtailed RAND's ability to question subcontractors and analyze many of the cost claims that had to be accepted as valid over the course of the analysis.

Table 7. Primary Factors for Block II to Block IIIf Unit Cost Increase (BY2001\$)

Factor	\$ Amount	Percent
Risk Premium Accounting Artifact	\$60m	30%
Storage and Restart Costs	\$57m	29%
Increased Component Costs	\$51m	26%
Other (e.g. SATCOM industry inflation, cost overruns)	\$29m	15%

The largest factor—almost one-third of the increase—is an accounting artifact where the Block IIIf prices, as calculated by the Program Office include a 15% risk premium, whereas Block II unit costs do not (because they largely reflect expended rather than projected costs). This results in an apples and oranges comparison. Inasmuch as the Block IIIf is practically identical to the Block II units that Boeing is already building, Boeing can be realistically expected to produce the satellites at near the target cost, which is 15% below the ceiling cost—although Block II is running 3% over target. But the ceiling price is what was reported. Next, Boeing is charging for storage and restart costs for the 2.5 year hiatus



between Blocks II and II^f. On the surface, the cause appears to be the interruption in production, but the four-year hiatus (measured, as noted, in terms of when satellites were ordered, not when they launched) between Block I and Block II had a cost of only \$3.5 million, or less than 7% of the current estimate. One explanation is that significant aspects of WGS production are no longer supported by the commercial market and therefore require storage and restart expenses during production breaks. Finally, key components of WGS that are no longer supplied to the commercial market will have greatly increased procurement costs accounting for another 26% of the cost increase. The second and third factors support the argument that the root causes of the breach are changes in the commercial market without corresponding changes in the WGS design and procurement

Despite these large cost increases, the WGS program is essentially healthy and relatively well managed. The satellites work; three of them are already on orbit serving customers. These customers are generally happy, which is part of the reason that the currently planned WGS constellation is larger than the one originally planned (more often, total buys decline over the life of a contract). There is no reason to expect that the cost of subsequent satellites after WGS 8 will increase; quite the contrary. Boeing's bid proposals for WGS 9 through 12 suggest that they will run \$100 million less than WGS 7 did (once due account is taken of the baseline inflation in the satellite industry). Thus, although the cost increases in what should be a stable program may appear startling (and remain somewhat startling even after explanation), this is no indicator of a program facing technological or production problems that cannot be reasonably solved.

The broader lesson learned for this program is that when DoD procurement piggybacks on a commercial base, notably the commercial base of a particular company, it takes a risk. The base may shrink, leaving it with less capacity to cover total overhead costs. Even if the base does not shrink, it will evolve. If DoD requirements do not evolve in parallel—and there is no inherent reason why they should—the divergence between the DoD's requirements and the market's requirements means that either the requirements are compromised (admittedly, this may be acceptable in some circumstances) or, eventually, such programs have to stand on their own feet. They can no longer be free riders, so to speak. This suggests that a certain procurement discipline is called for, or the DoD will pay the difference. Start-stop programs cost more than steady-state programs (i.e., when buys are consistent from one year to the next), which, in turn, are somewhat more costly than total buy programs. Although the DoD cannot necessarily commit to even procurements for a variety of reasons (e.g., changing requirements, risk management, congressional politics), everyone concerned should understand that maximizing acquisition flexibility entails costs.

WGS Conclusions

Three primary factors contribute to the Nunn-McCurdy breach: an accounting artifact, increase in the cost of component parts, and storage and restart costs. Each contributes to about one-third of the cost increase between Block II and II^f. An underlying factor of the increase, particularly with respect to the storage and restart costs, is the change that occurs in the commercial product base that affected the WGS costs. The government incurred additional costs because the commercial base of Boeing no longer supported the WGS. This probably would not have occurred if all Boeing had to do was pull parts from an active commercial line. Thus, when the government links one of its programs to a company's commercial base, it assumes an additional measure of risk.

Common Root Causes and Lessons Learned

We examined six programs (WGS, Apache Longbow, DDG-1000, Joint Strike Fighter, Excalibur, Navy, and Enterprise Recourse Planning) and identified the root causes



of their breaches. The root causes of the breaches were placed in three categories: planning, changes in the economy, and program management.

While these six programs reveal certain cost growth characteristics, they also reflect important differences in how and why cost growth occurred. This point is an important one for policy makers to keep in mind because they sometimes attempt to universalize policies as if all program cost increases stem from common causes.

Quantity increases or decreases figured into all six of the programs. However, RAND's experience suggests that while quantity change can affect a program in important ways, they are rarely the *root* cause of a Nunn-McCurdy breach. For example, the DDG-1000 program went from 10 ships to three, which naturally raised the unit cost and signaled a breach. But the reason for the quantity change stemmed from a recognition of changes in the operational environment. Similarly, the increase in the Apache quantities was driven by a decision to procure additional helicopters for operational reasons. Understanding the principle that quantity change is rarely a governing root cause for cost growth is fundamental to investigating cases where quantity changes accompany unit cost threshold breaches. The RAND experience to date shows that although programs had associated quantity changes when they incurred N-M breaches that triggered RCA examinations, in each case, the quantity change was grounded in other program-specific factors that resulted in unit cost growth. Uncovering the grounds upon which quantity changes are founded is an important part of the thorough and insightful RCAs demanded by the WSARA.

Based upon our research of the three programs covered by this report, and an examination of similarities and differences, RAND offers three overarching recommendations:

1. In the development of early program planning, understand thoroughly the implication of the testing regimes and the numbers of test articles required to execute those regimes. Planning for the testing regime and use of simulation cannot be overstated. The F-35 exemplified that problem.
2. Clearly stipulate costing methodologies that rely on commercial production or even commercial production practices. The danger is both that necessary cost controls will not be implemented and that important cost analysis alternatives will not be recognized and used. In the WGS satellite program, there does not appear to be a good understanding that fabricating a vehicle to be used by the military can cost significantly more than a commercial vehicle with an international "list price."
3. Where a program depends upon planned product improvements over time, ensure a clear understanding of relationships among several factors, primarily time in inventory, ongoing research and development, and periodic platform upgrades or blocks through the entire out-year period. Failure to understand this can cause PMs to lose sight of program cost growth, as was the case with the Apache Longbow.

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